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All communications should be addressed to the Editor.

No. 94. OCTOBER, 1918. VOL. XXII.

Notices of the Royal Aëronautical Society.

Appointments.

Mr. A. A. Remington, Associate Fellow, has been elected President of the Institute of Automobile Engineers for the ensuing year.

Mr. A. E. Berriman, Fellow, has been appointed Deputy Controller of the Technical Department of the Air Group of the Ministry of Munitions of War.

The Syllabus.

Appended is a list of the lectures to be delivered before the Society during the ensuing session. The lectures on November 8th, December 11th, and January 8th will be given in the Central Hall, Westminster, the remainder will be at the Royal Society of Arts:—

1918.

Friday, November 8th.—"Fighting in the Air," by Major Cochrane Patrick, D.S.O., R.A.F. The Lecture will be given in the Central Hall, Westminster. The chair will be taken at 7.45 by Major-General W. S. Brancker, R.A.

Wednesday, November 20th.—"Stress Optical Experiments," by Major A. R. Low, R.A.F., M.A. Chair to be taken at 7.45 by Major L. N. G. Filon.

Thursday, December 5th.—"Shop Practice in Respect to Aircraft Steels," by Brigadier-General R. K. Bagnall Wild, C.M.G., R.E. Chair to be taken at 7.45 by Sir Robert Hadfield, F.R.S.

Wednesday, December 11th.—"Civil Aerial Transport: Is it Practicable, is it Safe, and is it Profitable?" by Claude Grahame-White. The Lecture will be given in the Central Hall, Westminster. The chair will be taken at 3 p.m. by the Right Hon. Lord Northcliffe. Popular Lecture.

Wednesday, December 18th.—"Full Scale Aeroplane Experiments," by Captain W. S. Farren, C.B.E. Chair to be taken at 7.45 by Lieutenant-Colonel M. O'Gorman, C.B.

1919.

Wednesday, January 8th.—"To Constantinople and Back by Aeroplane in War Time," by F. Handley-Page, C.B.E. Chair to be taken at 3 p.m. by Major Alan H. Burgoyne, M.P. The Lecture will be given in the Central Hall, Westminster. **Juvenile Lecture.**

Wednesday, January 15th.—"Medical Aspects of Aviation," by L. E. Stamm, B.A., B.Sc., M.D., R.A.F. The chair to be taken at 7.45 p.m. by Surgeon-General Sir Alfred Keogh, G.C.B., M.D.

Wednesday, January 29th.—"The Rigging of Aeroplanes," by Captain R. J. Goodman Crouch, R.A.F. Chair to be taken at 7.45 by Lieutenant-Colonel A. Ogilvie, R.A.F.

Wednesday, February 12th.—"Fabrics and Dope, with Special Reference to Deterioration and Tautness," by F. W. Aston, M.A., D.Sc., of the Royal Aircraft Establishment. Chair to be taken at 7.45.

Wednesday, February 26th.—"Some Points on Aeroplane Design," by Captain F. S. Barnwell, R.A.F. Chair to be taken at 7.45 by General J. Weir, R.A.F.

Wednesday, March 12th.—"From Model to Full Scale in Aeronautics," by H. Levy, of the National Physical Laboratory. Chair to be taken at 7.45 by Dr. T. E. Stanton, F.R.S.

Wednesday, March 26th.—"Lighter-than-Air Craft," by Lieutenant-Colonel T. R. Cave-Brown-Cave. Chair to be taken at 7.45 by Brigadier-General E. Maitland, D.S.O.

Wednesday, April 9th.—

Wednesday, April 26th.—"Aluminium Alloys for Aeroplane Engines," by Professor F. C. Lea, F.R.S. Chair to be taken at 7.45 by Lieutenant-Colonel Jenkyn.

Discussion will take place after each lecture.

The "Wilbur Wright" Lecture will be given in May. Details will be announced later.

The Annual General Meeting will be held in the Offices of the Society at 5 p.m. on March 19th.

The Manchester Branch.

The inaugural meeting of this Branch will be held in the Manchester College of Technology on Tuesday, November 12th, at 7.30 p.m. The Branch is a promising one, and the initial arrangements have been made by Mr. F. E. Broadsmith, Associate Fellow, of A. V. Roe & Co., Ltd.

The Hendon Branch.

This Branch is approaching completion. Mr. M. A. S. Riach, Fellow, of Grahame-White, Ltd., Mr. R. O. Boswell, Fellow, of Handley-Page, Ltd., and Mr. G. Watts, Fellow, of The Aircraft Manufacturing Co., Ltd., have the arrangements in hand. An announcement of the inaugural meeting will be made at an early date.

DESIGN OF AEROPLANE STRUTS.

BY W. H. BARLING, A.R.C.SC., B.SC., AND H. A. WEBB, M.A., ASSOCIATE FELLOWS.

The failure of struts under end load is due to two causes, crushing, due to direct compression, and excessive bending, due to elastic instability. In a general way we may say that the end portions of the strut tend to fail by crushing and the middle portion tends to fail by bending, but we cannot make a rule to decide where the middle portion ends and the end portions begin, because both causes are really operating simultaneously all along the strut, and we can only form a vague impression of their relative importance at various sections of the strut. A parallel strut, for instance, unless it is very short, will fail by bending at or near the middle, and the end portions will show no signs of crushing; so we may fairly infer that weight can be saved in a solid wooden strut without much loss of strength by tapering the ends; and that on the whole the efficiency of a strut, as measured by the ratio of crippling end load to weight or (resistance + m weight) where m* is a fraction, can be improved by tapering. If, however, the taper is too severe, the ends of the strut will crush before the middle portion shows signs of failure by bending. And if the taper is gradual, but incorrectly designed, it will be found that the strut will fail at or near some definite section (it might be, for instance, at $\frac{3}{4}$ length), that being the section which, under the combined influence of direct compression and elastic instability, is weakest.

Nearly 150 years ago the great French mathematician, Lagrange, considered the problem of tapered struts. He was not interested in aeroplanes, so far as we know, but in ancient times Vitruvius had recommended architects to taper their columns, and Lagrange noticed that many architects did so; but when he asked them why, they had no better reason to give him than an analogy from the shape of the human body. This was inconclusive, since different people of the same height have very different tapers, so Lagrange decided to examine the problem mathematically. He considered several tapers and found they were all worse than useless. This conclusion was correct, and he was too good a mathematician to make a mistake on such a point. But he then inferred that tapering was essentially bad, and that the parallel strut was the best possible.

This inference was wrong; Lagrange had not drawn his conclusion from a large enough range of examples.

A badly tapered strut may be much worse than a parallel one, an error present in most aeroplanes earlier than 1915, and even in some present-day machines.

In the summer of 1914 the authors deduced a strut shape which, both by theory and by test, gave considerably better results than parallel struts of the same weight.

Struts of this shape have been used in great quantities ever since, R.E.7 being the first machine.

Considerable experience and work (1915) on these struts have led to the conclusion that no appreciable improvement in shape can be made.

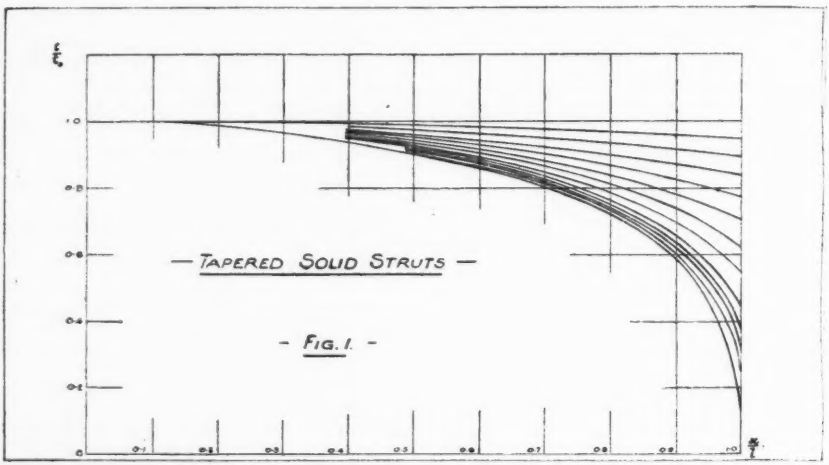
If f lbs. per square inch is the maximum stress that we decide to allow in the strut, it seems likely that the best strut is one in which, as the end load rises and the strut deflects, the maximum stress at *every* section of the strut reaches the value f simultaneously, since such a strut would in theory, given uniform

* The value of m depends on the case under consideration. A common value is $\frac{1}{3}$ or $\frac{1}{4}$.

material and perfect construction, fail at every section at once. This assumption is not quite obvious, but we established it rigorously for solid struts by means of the calculus of variations in 1915.

The theory of these struts is indicated in Appendix I. The practical results are shown in Fig. 1. The taper depends on the load the strut has to carry, a sharper taper being used on a lightly loaded strut. Correct tapering saves 13% of weight, and (if the struts are exposed to the air) 8% of resistance, on all except heavily loaded short struts.

Many such struts have been tested from time to time, and are found, as a rule, to develop cracks on the compression face at several points along the length simultaneously in confirmation of the theory.



The Effect of Lateral Wind Load on Struts.

When an aeroplane side-slips the lateral wind load tends to increase the deflection of the struts. If allowance is to be made for this in design, no sensible alteration in the taper is necessary, and allowance can be made by designing the strut to support a somewhat higher load than would otherwise be required.

As an example, if the forward speed of the aeroplane is 130 miles an hour, a streamline spruce strut 6 feet long, with a crippling load of 2,000lbs., would have its crippling load reduced 12% by side-slip. Stiffening the strut to enable it to support side-slip would add 6% to its weight and 3% to its resistance. On stiffer struts the effect of side-slip is much less. Probably in the design of the wing struts of fast scouts side-slip should be considered; in slower machines it is not at present important.

Short Wooden Struts.

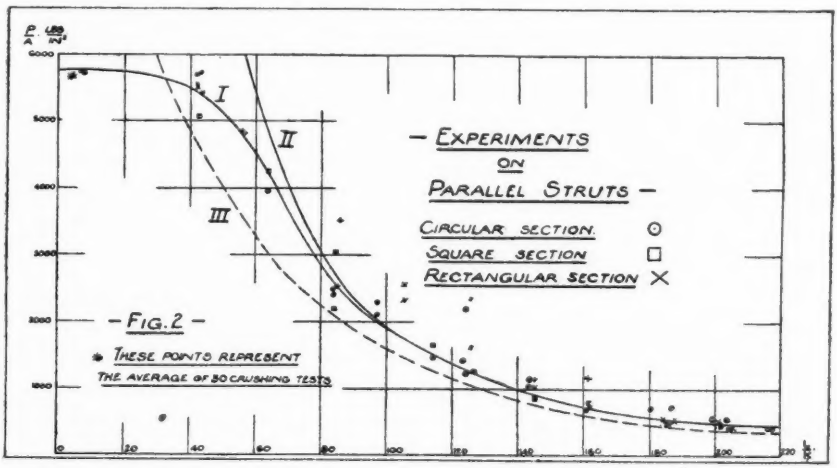
It is well known that Euler's formula for the crippling load of *parallel* struts, viz.,

$$P = \frac{\pi^2 EI}{L^2}$$

which is based on elastic instability only and neglects crushing, gives good results

for long struts, but gives too high a value of the crippling load for short struts. The discrepancy is commonly attributed to two causes, viz., initial curvature of the strut, due to warping, which is probably more noticeable in wood than in metal; and eccentricity of end load, which probably depends mainly on the nature of the end fittings. It can be shown mathematically that both these causes have a small effect on the crippling load of long struts and a large effect on the crippling load of short struts. Further, it was pointed out by Professor Perry in 1886 that the effects of initial curvature and of eccentricity on the behaviour of the strut are mathematically similar, and may both be allowed for by the assumption of a certain fictitious eccentricity of end load to be determined by comparing the results of experiment and calculation.

To test this theory, and also to check the values of E and f used in design, experiments were made in 1916 at the R.A.F. on the crippling loads of fifty parallel spruce struts of circular, square and rectangular sections, and of widely



varying dimensions. The lengths of the struts varied from 1 to 4 feet, and their cross sectional areas from ½ sq. in. to 2 sq. in. In the rectangular sections the ratio of the sides varied from 2 to 1 to 4 to 1. The struts were tested with pin-jointed ends, the fittings being specially constructed to ensure that the load should be as nearly central as possible. The results of the tests are shown graphically in Fig. 2.

It may be noticed that:—

(*a*) Euler's formula, represented by Curve II., gives good results for long struts.

(*b*) Gordon's formula, represented by Curve III., does not represent the facts.

(*c*) The Curve I. represents a fair average of the facts, and is drawn from the theoretical formula for an eccentrically loaded parallel strut, *on the assumption that the eccentricity is proportional to the least diameter of the strut.* We claim that this assumption is justified by the R.A.F. experiments. That the *real* eccentricity of load should be proportional to the diameter of the end fitting seems likely enough. But it must be remembered that we are dealing with what

is probably a fictitious eccentricity, in fact, an empirical coefficient, depending on other things besides end fittings; and that is why we have appealed to experiment for justification.

Next we propose to assume, for the design of short *tapered* struts, that the eccentricity is proportional to the diameter of the end fittings, for all fittings of a given type, *whether the strut is parallel or tapered.*

As regards the real eccentricity, this assumption seems reasonable. As regards other causes, such as initial curvature, it is not obvious. But it must be remembered that *the tapered strut, having smaller ends, has lighter fittings than the parallel strut*, and as we propose to make no allowance for this point, it is probable that our assumption does not, on the whole, favour the tapered strut over the parallel strut; rather, if anything, the reverse.

Another interesting point in Fig. 2 is that struts of rectangular section, shown by crosses, are on the average, though there are exceptions, stronger than struts of square or circular section. Probably this is due to non-uniformity of material. The square and circular struts deflect in their weakest direction, if all directions are not equally strong. The rectangular struts have their direction of deflection prescribed for them, and this is naturally not usually, *though it is sometimes*, the direction in which the material is weakest. For the same reason tests on streamline struts, because they have their direction of deflection prescribed for them, give on the average, *though there are exceptions*, better results than tests on square or circular struts; but it would be rash to rely in design on the apparent extra strength of streamline struts, which must be regarded as exceptional, though such exceptions be more frequent than the rule.

The correct taper for short struts is shown in Fig. 1. Tapering saves 12 or 13% of weight on all struts whose length is more than 20 diameters.

It should be noticed that the crippling load of the tapered strut is not stated in Fig. 1, because it depends on the eccentricity. But the designer is presumed to know from experiment the crippling load of the parallel strut that this tapered strut is designed to replace.

Struts in the Fuselage.

A common type of fuselage struts in a tractor machine consists of a parallel middle portion with two conical ends. For the best results the parallel portion should be 40% of the total length of the strut. If correctly designed, these struts will be nearly 10% lighter than parallel struts. (See Fig. 2A.)

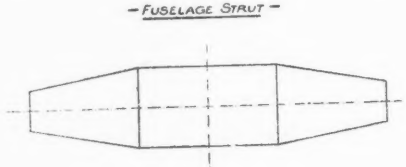
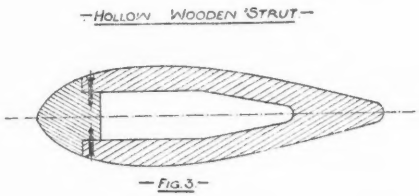


FIG. 2A.

Hollow Tapered Struts.

An efficient type of strut for large machines is a tapered wooden strut containing a parallel or untapered hole running the whole length of the strut. Data for design are given in the Appendix to this paper. Struts of this type were first designed by the authors towards the end of 1915, and have proved satisfactory.

As most hollow wooden struts warp badly the authors then devised and used the construction shown in Fig. 3.

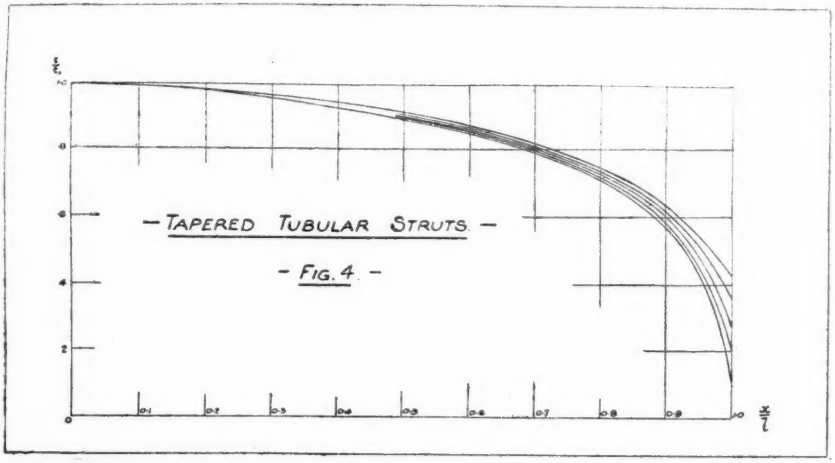


Here the two different pieces forming the strut A and B are still symmetrical about the centre line OO and have inherently little tendency to warp perpendicular to OO. The strut is too stiff to warp about its other axis.

The hollow portion in such struts should preferably be parallel along the length for manufacture reasons.

With such struts the end fittings may be placed inside in the case of large machines.

Another type of strut that is theoretically efficient is a tapered tubular strut of uniform gauge, whether made of metal or of layers of plywood. The correct taper is shown in Fig. 4. These struts are 10% lighter and have 10% less resistance than parallel struts of the same material and gauge. It may be doubted, however, whether struts of this type will ever come into general use, as special skill and machinery are required for their manufacture.



Faired Steel Tubes.

This is a popular form of strut as it allows simple end fittings and is cheap.

A point of considerable importance sometimes overlooked is that the fairing itself generally strengthens up the tube by a large percentage.

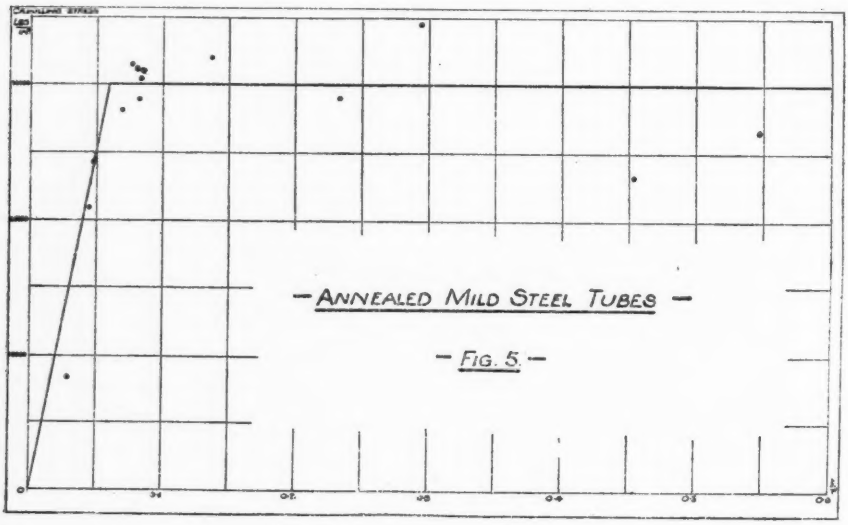
It often pays to use fairly thick, well attached fairings and to rely on them for strength.

Pilots, mechanics and others require to be educated on this point as it is popularly supposed that fairings are for reduction of resistance only. The faired steel tube is not fairly treated if this view be taken.

An important point in connection with the use of annealed steel tubes for struts, whether M.S. or H.T.S., is what is called the "crinkling stress." The stress f, to which we have often referred this evening, is intended to mean the stress at which the relation between stress and strain departs appreciably from the straight line law. This is sometimes identical with the elastic limit of the material, but in hollow steel structures it is often not identical; and then for f the value of crinkling stress must be taken.

For example, tubes in compression fail by the formation of circular, oval, or polygonal crinkles, generally close to the ends of the tube, and by the "crinkling stress" is meant the stress in pounds per square inch at the beginning of the formation of the first crinkle, and this may occur at a stress below the elastic limit of the material.

The result of tests made at the R.A.F. in 1914 on short annealed mild steel tubes is shown in Fig. 5. The tests are plotted on a base of



$$\frac{t}{r} = \frac{\text{thickness}}{\text{mean radius}}$$

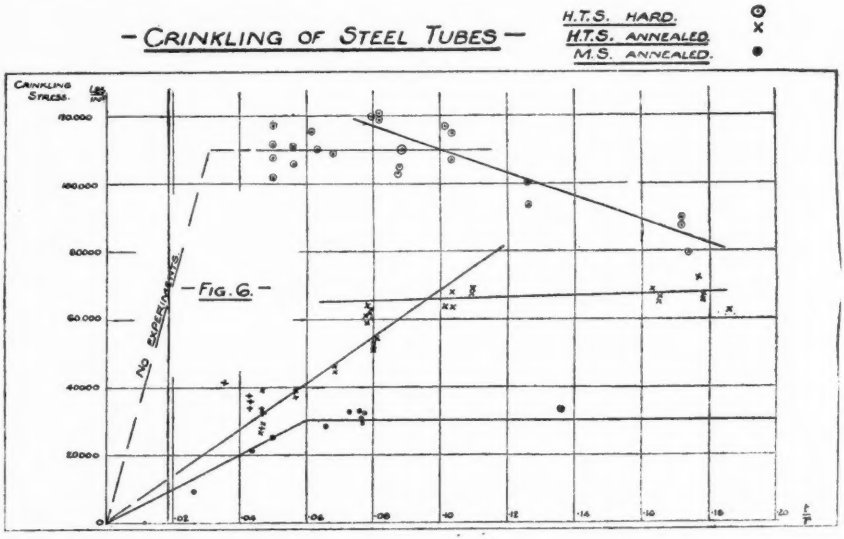
and it will be noticed that if $t/r > .06$, the crinkling stress is 30,000 lbs. per sq. in. But that if $t/r < .06$, the crinkling stress drops rapidly by a straight line law. For instance, for a tube of 3 inch diameter and 22G, the crinkling stress is only about 10,000 lbs. per sq. inch. The importance of this is obvious, since it is to the interest of designers, if it were not for crinkling stress, to use thin tubes, to get greater stiffness without increase of weight.

As the cause of crinkling was obscure, and as data for the design of H.T.S. struts were urgently needed, Mr. Garnett, the Principal, and Dr. Field, Professor of Mechanical Engineering at the Manchester School of Technology, kindly under-

took to test in their laboratory tubes supplied by the R.A.F. An account of these tests was published last October in the "Proceedings of the Institution of Civil Engineers," in a paper, entitled, "The Failure of Short Tubular Struts of High Tensile Steel," by Popplewell and Carrington. This paper should be read by every designer who uses H.T.S. tubes in compression.

The tests were performed with an elaboration and an attention to detail that reflect great credit on the care and patience of Mr. Carrington, the experimenter, and make the paper of classical importance.

The results on annealed tubes are shown in Fig. 6, given here by the kind permission of the authors of the paper. It will be noticed that the diagram is



similar to that for mild steel, except that the critical region occurs when $t/r = .1$ instead of .06. If $t/r > .1$ the crinkling stress is 65,000 lbs. per sq. in. If $t/r < .1$ the crinkling stress drops rapidly by a straight line law. For instance, it would be rash to use an annealed H.T.S. tube of 3 inches diameter and 22G in circumstances requiring a crinkling stress in excess of 12,000 lbs. per sq. in.

APPENDIX I.

I.—MATHEMATICAL THEORY.

§ (1) The strut, Fig 7, of length $L = 2l$ inches, is assumed to have frictionless pin joints at its end AA. Axes OX, OY are taken as in the figure.

The strut deflects under a given end load P lbs. Eccentricity of end load $= e$ inches, a given quantity. For the cross section of the strut distant x inches from O, the centre of the strut,

Maximum thickness perpendicular to the neutral axis ... $= t$ inches.
Moment of inertia of cross section about neutral axis ... $= I$ inch units.

(The neutral axis being perpendicular to the plane of the paper.)

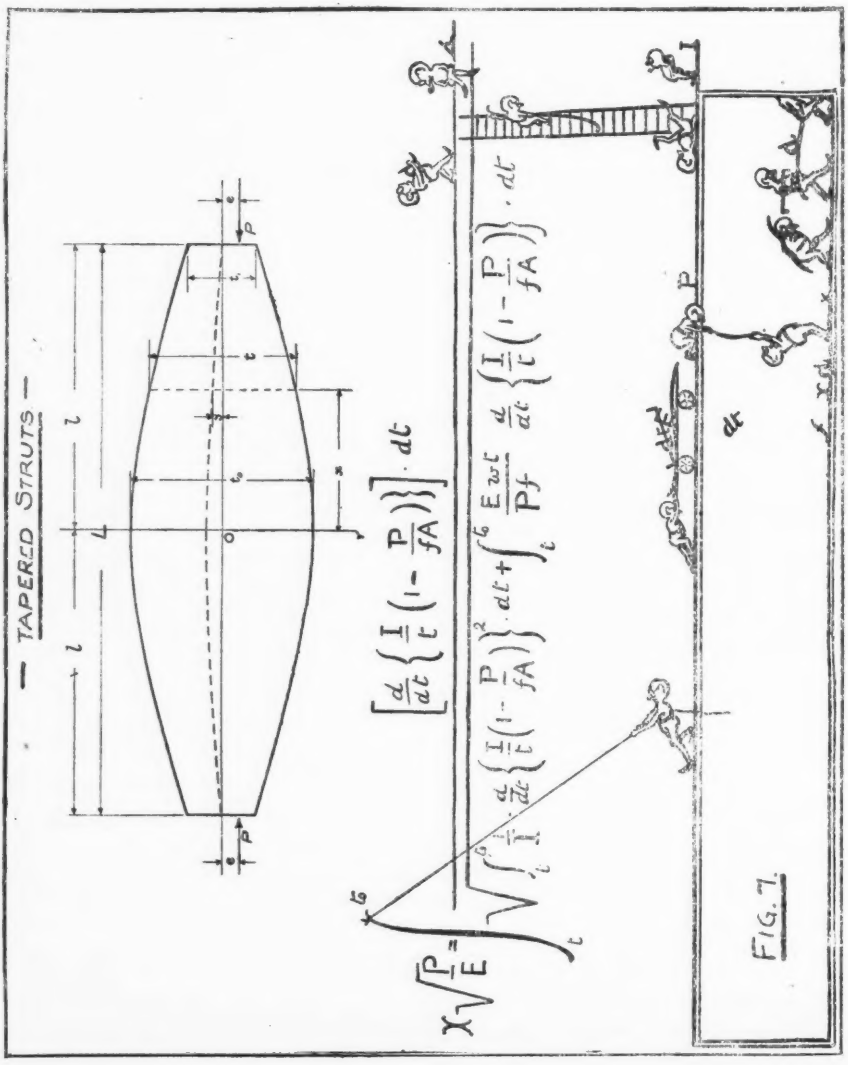
Area of cross section ... ... $= A$ sq. in.
Deflection under load P ... ... $= y$ inches.

I and A are *any given* functions of t. t, I and A have the values t_0, I_0 and A_0 at the central section of the strut, and t_1, I_1 and A_1 at the ends of the strut.

There is a lateral load on the strut equal to wt lbs. per inch length of the strut in the plane of the paper, *i.e.*,

$$\textit{total} \text{ lateral load on strut} = \int_{x=-l}^{x=l} wt \, . \, dx \text{ lbs.}$$

w is supposed to be a *given* function of x; if all the sections of the strut are similar, and the lateral load is due to wind pressure, w will be constant.



The *meridian curve* of the strut is defined to be the curve whose ordinate is $\frac{1}{2}t$ and whose abscissa is x.

§ (2) It is required to find the shape of the meridian curve, so that under the end load P the maximum compressive stress at *every* cross section of the strut

$$= f \text{ lbs. per sq. in.}$$

The bending moment at the cross section PP is

$$\{ P(y+e) - \int^x \int^x wt \, . \, dx \, . \, dx \} \, .$$

$\therefore$ the maximum compressive stress at this section is

$$\frac{\{ P(y+e) - \int^x \int^x wt \, . \, dx \, . \, dx \} \, . t}{2I} + \frac{P}{A} = f \quad . \quad . \quad . \quad . \quad (1)$$

The bending moment equation gives

$$-EI\frac{d^2y}{dx^2} = P(y+e) - \int^x \int^x wt \, . \, dx \, . \, dx \quad . \quad . \quad . \quad (2)$$

where E lbs. per sq. in. is Young's modulus of elasticity.

Eliminate y from (1) and (2)

$$\therefore \frac{d}{dt}\left\{\frac{I}{t}\left(1 - \frac{P}{fA}\right)\right\} \cdot \frac{d^2t}{dx^2} + \frac{d^2}{dt^2}\left\{\frac{I}{t}\left(1 - \frac{P}{fA}\right)\right\} \cdot \left(\frac{dt}{dx}\right)^2 = \frac{wt}{2f} \, .$$

$$= -\frac{P}{EI} \cdot \left\{\frac{I}{t}\left(1 - \frac{P}{fA}\right)\right\} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

This is the differential equation that gives the meridian curve of the strut. To solve it, multiply by

$$2 \cdot \frac{d}{dt}\left\{\frac{I}{t}\left(1 - \frac{P}{fA}\right)\right\} \cdot \frac{dt}{dx}$$

and integrate.

We find that

$$x\sqrt{\frac{P}{E}} = \int_t^{t_0} \frac{\left[\frac{d}{dt}\left\{\frac{I}{t}\left(1 - \frac{P}{fA}\right)\right\}\right] \, . \, dt}{\sqrt{\int_t^{t_0} \frac{1}{I} \cdot \frac{d}{dt}\left\{\frac{I}{t}\left(1 - \frac{P}{fA}\right)\right\}^2 \, . \, dt + \int_t^{t_0} \frac{Ewt}{Pf} \cdot \frac{d}{dt}\left\{\frac{I}{t}\left(1 - \frac{P}{fA}\right)\right\} \, . \, dt}} \quad (4)$$

Since at the end of the strut, $x = l$ and $y = o$, we have from (1)

$$\frac{I_1}{t_1}\left(1 - \frac{P}{fA_1}\right) = \frac{Pe}{2f} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

which gives t_1.

Substituting $x = l$ and $t = t_1$ in (4), we have an equation which theoretically determines t_0.

§ (3) **Solid Struts, Lateral Load Neglected.**

All the cross sections of the strut are assumed to be similar and similarly situated curves

$$\left.\begin{aligned} \therefore A &= at^2 \\ I &= bt^4 \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where a and b are given constants.

Put $t = t_0 \cos\phi$, and we find from (4) that

$$x \cdot \sqrt{\frac{P}{3EI_0}} = \int_0^{\phi} \frac{\left(\cos^2\phi - \dfrac{P}{3fA_0}\right) \cdot d\phi}{\sqrt{1 + \dfrac{8P \log_e \cos\phi}{3fA_0 \sin^2\phi} + \dfrac{P^2 \sec^2\phi}{3f^2A_0^2}}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and

$$\frac{t_1^2}{t_0^2} = \frac{P}{fA_0}\left(1 + \frac{ae}{2bt_1}\right) = \cos^2\phi_1 \quad . \quad . \quad . \quad (8)$$

give t_1 and ϕ_1.

Substituting $x = l$ and $\phi = \phi_1$ in (7), we have an equation which theoretically determines t_0.

For a strut of given length, for any assumed value of the eccentricity e a family of meridian curves can be drawn from these equations corresponding to various values of P/fA_0, the integral in (7) being found graphically; and for various assumed values of e a series of such families can be drawn. This has been done for a large number of values of e and of P/fA_0.

It is found that for struts of given length, central section and end sections, i.e., for given values of L, t_0 and t_1, the curves are nearly identical, whatever the value of e, although of course the value of the crippling load P depends on e. In fact, if these curves are drawn on the assumption that $e = o$, and are then used for other values of e, the error in t will never exceed 1/5 per cent.

Accordingly, the curves in Fig. 1 have been drawn from equations (7) and (8) on the assumption that $e = o$; they may be taken as correct to the limits of drawing accuracy for all values of e.

The value of the crippling load P has been calculated on the assumption that $e = o$, and is given by the curve in Fig. 1A, and may be taken as fairly correct for other values of e if

$$\frac{P}{fA_0} < 0.2,$$

but not otherwise.

§ (4) **Weight and Resistance Saved by Tapering.**

The weight and resistance saved by tapering have been calculated for several values of e/t_1, ranging from 0 to 0.2 and *are found to be nearly independent of eccentricity for struts of given L, t_0 and t_1*, being somewhat greater for large eccentricities. As no account has been taken of the fact that smaller fittings mean an additional saving of weight and resistance, the results may be taken as a conservative estimate for all values of e/t_1.

§ (5) **Solid Struts with Lateral Wind Load.**

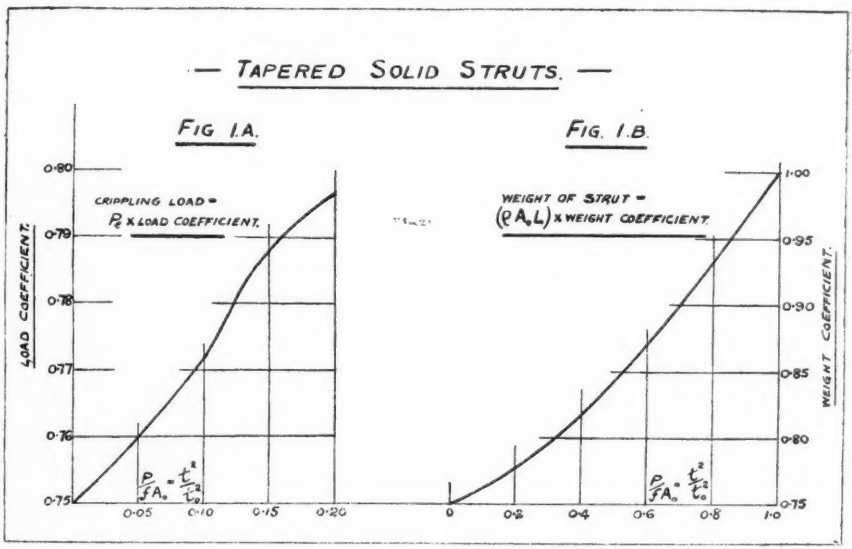
We find from equation (4) that

$$x \cdot \sqrt{\frac{P}{3EI_0}} = \int_0^{\phi} \frac{\left(\cos^2\phi - \frac{P}{3fA_0}\right) \cdot d\phi}{\sqrt{1 + \frac{8P \log_e \cos\phi}{3fA_0 \sin^2\phi} + \frac{P^2 \sec^2\phi}{3f^2A_0^2} + \frac{wE}{6f^2a}\left\{-1 + \frac{3fA_0}{2P}(1 + \cos^2\phi)\right\}}} \quad (9)$$

As before,

$$\frac{t_1^2}{t_0^2} = \frac{P}{fA_0}\left(1 + \frac{ae}{2bt_1}\right) = \cos^2\phi_1 \quad . \quad . \quad . \quad . \quad (8)$$

give t_1 and ϕ_1.



Substituting $x = l$ and $\phi = \phi_1$ in (9), we have an equation which theoretically determines t_0.

As it is long and lightly loaded struts that will be most affected by wind, we may take $e = 0$.

**If the forward speed of the aeroplane is 130 miles per hour, with a ten degree angle of yaw*, we have for spruce struts

$$\frac{wE}{f^2a} = 0.02 \text{ roughly} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

* 10° is the angle of yaw that gives the greatest lateral wind load (see the Technical Report of the Advisory Committee for Aeronautics, 1912-13, p. 114.

Meridian curves of several struts have been drawn from these data. It is found that lateral wind load, like eccentricity, has little effect on the shape of the strut, but reduces its crippling load. *The percentage reduction of crippling load due to lateral wind load is given approximately by*

$$\tfrac{3}{4} \cdot \frac{fA_0}{P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

if

$$\frac{P}{fA_0} > 0.05.$$

We infer that the correction for lateral wind load is not worth making except for the wing struts of high speed machines.

§ (6) **Struts in the Fuselage.**

The diameter of the parallel portion of the strut should be 1% less than the central diameter of the strut tapered as in Fig. 1. The method of design is illustrated in Example IV.

II.—NUMERICAL EXAMPLES.

Example I.a.

To design a tapered *solid wooden* pin-jointed streamline strut, 70 inches long, to support an end load of 2,000 lbs., lateral wind load being neglected.

It is given that

$$E = 1.6 \times 10^6 \text{ lbs. per sq. inch,}$$

that the maximum allowable compressive stress

$$f = 5{,}500 \text{ lbs. per sq. inch,}$$

that the density of the wood is

$$\rho = 0.018 \text{ lbs. per cubic inch,}$$

and that the shape of the cross section is such that*

$$A = 2.18\ t^2 \text{ sq. inches,}$$
$$\text{and } I = 0.130\ t^4 \text{ inch units.}$$

We have $P = 2{,}000$ lbs.,

and $L = 70$ inches.

$\therefore$ t_0 is given *approximately* by

$$P = (0.8)\, P_e = (0.8) \frac{\pi^2 E I_0}{L^2}$$

$$\therefore \quad I = \frac{2{,}000 \times (70)^2}{0.8 \times \pi^2 \times 1.6 \times 10^6} = 0.776$$

$$\therefore \quad t_0^4 = \frac{I_0}{0.130} = \frac{0.776}{0.130} = 5.97.$$

$$\therefore \quad t_0^2 = 2.44 \text{ and } t_0 = 1.56 \text{ inches}$$

* These values correspond approximately to a streamline strut of fineness ratio 3.

$$\therefore \quad A = 2.18\, t_o^2 = 5.34 \text{ sq. inches}$$

$$\therefore \quad \frac{P}{fA_o} = \frac{2{,}000}{5{,}500 \times 5.34} = 0.068.$$

All these values have been *approximate*.

The curve in Fig. 1A enables us to find them *more accurately*.

Since $\dfrac{P}{fA_o} = 0.068$

$\dfrac{P}{P_e} = 0.764$ (instead of the approximate value 0.8 used above).

$$\therefore \quad I_o = 0.813$$

$$\therefore \quad t_o^4 = \frac{I_o}{0.130} = 6.25$$

$$\therefore \quad t_o^2 = 2.50 \text{ and } t_o = 1.58 \text{ inches.}$$

$$\therefore \quad A_o = 5.45 \text{ sq. in. and } \frac{P}{fA_o} = 0.0667$$

$$\therefore \quad \frac{t_1}{t_o} = \sqrt{\frac{P}{fA_o}} = 0.258.$$

From the curves in Fig. 1, we find by interpolation the values

x/l =	0	2/7	4/7	6/7	33/35	1
t/t_o =	1	.975	.887	.680	.527	.258

Hence, since $l = 35$ inches and $t_o = 1.58$ inches, the values

t inches =	1.58	1.54	1.40	1.07	0.83	0.41
x inches =	0	10	20	30	33	35

define the meridian curve of the strut.

The weight of the strut, from the curve in Fig. 1B,

$$= (0.757)\,(\rho A_o L) \text{ lbs.}$$
$$= 0.757 \times 0.018 \times 5.45 \times 70 \text{ lbs.}$$
$$= 5.20 \text{ lbs.}$$

This strut has 13 per cent. less weight and 8 per cent. less air resistance than a parallel strut of the same material.

Example I.b.

To design the strut in Example I.a, taking lateral wind load into account.

From (11) the effect of lateral wind load is to reduce the crippling load by

$$\tfrac{3}{4}\,\frac{fA_o}{P} = \frac{3}{4 \times 0.0667} = 11.2 \text{ per cent.}$$

We can therefore compensate for this by designing a strut to support

$$2{,}000 \times \frac{100}{88.8} = 2{,}250 \text{ lbs. neglecting wind.}$$

Such a strut will support 2,250 lbs. with wind neglected, or 2,000 lbs. taking wind into account.

Proceeding exactly as in Example I.a, we find that

t inches =	1.63	1.59	1.45	1.11	0.87	0.43
x inches =	0	10	20	30	33	35

define the meridian curve of the strut, which weighs 5.51 lbs.

Taking lateral wind load into account has added 6 per cent. to the weight and 3 per cent. to the resistance of the tapered strut.

Example II.a.

To design a tapered *solid wooden* pin-jointed streamline strut, 80 inches long, to support an end load of 10,000 lbs. with the same data as in Example I.a, lateral wind load being neglected.

We have $P = 10{,}000$ lbs.,
and $L = 80$ inches.

$\therefore$ *approximately*

$$I_o = \frac{10{,}000 \times (80)^2}{0.8 \times \pi^2 \times 1.6 \times 10^6} = 5.06$$

$$\therefore \quad t_o^4 = \frac{I_o}{0.130} = 38.9$$

$$\therefore \quad t_o^2 = 6.24 \text{ and } t_o = 2.50 \text{ inches}$$

$$\therefore \quad A_o = 2.18\ t_o^2 = 13.6 \text{ sq. inches}$$

$$\therefore \quad \frac{P}{fA_o} = \frac{10{,}000}{5{,}500 \times 13.6} = 0.134.$$

All these values have been *approximate;* the curve in Fig. 1A enables us to find them *more accurately.*

Since $\dfrac{P}{fA_o} = 0.134$

$\dfrac{P}{P_2} = 0.783$ (instead of the approximate value 0.8 used above).

$$\therefore \quad I_o = 5.18$$

$$\therefore \quad t_o^4 = \frac{I_o}{0.130} = 39.8$$

$$\therefore \quad t_o^2 = 6.31 \text{ and } t_o = 2.51 \text{ inches}$$

$$\therefore \quad A_o = 13.8 \text{ sq. inches and } \frac{P}{fA_o} = 0.132$$

$$\therefore \quad \frac{t_1}{t_o} = \sqrt{\frac{P}{fA_o}} = 0.363.$$

From the curves in Fig. 1, we find by interpolation the values

x/l	= 0	1/4	1/2	3/4	9/10	1
t/t_o	= 1	.981	.920	.791	.632	.363

Hence, since $l = 40$ inches and $t_o = 2.51$ inches, the values

x inches	= 0	10	20	30	36	40
t inches	= 2.51	2.47	2.31	1.99	1.59	0.91

define the meridian curve of the strut.

The weight of the strut, from the curve in Fig. 1B,

$$= (0.769)\ (\rho A_o L) \text{ lbs.}$$
$$= 0.769 \times 0.018 \times 13.8 \times 80 \text{ lbs.}$$
$$= 15.3 \text{ lbs.}$$

This strut has 13 per cent. less weight and 8 per cent. less air resistance than a parallel strut of the same material.

Example II.b.

To design the strut in Example II.a, taking lateral wind load into account.

From (11), the effect of lateral wind load is to reduce the crippling load by

$$\tfrac{3}{4}\frac{fA_o}{P} = \frac{3}{4 \times 0.132} = 5.7 \text{ per cent.}$$

We can therefore compensate for this by designing a strut to support

$$10{,}000 \times \frac{100}{94.3} = 10{,}600 \text{ lbs. neglecting wind.}$$

Such a strut will support 10,600 lbs. with wind neglected or 10,000 lbs. taking wind into account.

Proceeding exactly as in Examp'e II.a, we find that

t inches	= 2.55	2.50	2.34	2.02	1.62	0.94
x inches	= 0	10	20	30	36	40

define the meridian curve of the strut, which weighs 15.7 lbs.

Taking lateral wind load into account had added 2½ per cent. to the weight and 1 per cent. to the resistance of the tapered strut.

Example III.

To design a tapered solid strut to replace a parallel streamline solid strut, 40 inches long and 2 inches broad, with the same data as in Example I.a.

We have $L = 40$ inches,
$t = 2$ inches.

This strut is too short to support its Euler load " P."

$$" P " = \frac{\pi^2 EI}{L^2} = \frac{\pi^2 \times 1.6 \times 10^6 \times 0.130 \times (2)^4}{(40)^2} = 20{,}500 \text{ lbs.}$$

$$\therefore \frac{" P "}{fA} = \frac{20{,}500}{5{,}500 \times 2.18 \times 4} = 0.428.$$

$\therefore$ approximately, since A_0 is roughly 10 per cent. greater than A

$$\frac{t_1^2}{t_0^2} = \frac{" P "}{fA_0} = \frac{0.428}{1.1} = 0.388.$$

$\therefore$ from Fig. 1B, the weight of the tapered strut $= (0.814)\, A_0 L$, and this is to be 12 per cent. less than the weight of the parallel strut having similar end fittings.

$\therefore$ *more accurately*

$$(0.814)\, \rho A_0 L = (0.88)\, \rho A L,$$

$$\therefore \frac{t_0^2}{t^2} = \frac{A_0}{A} = \frac{0.88}{0.814} = 1.08$$

$$\therefore \frac{t_0}{t} = 1.04 \text{ and } \therefore t_0 = 2.08 \text{ inches}$$

$$\therefore \frac{t_1^2}{t_0^2} = \frac{" P "}{fA_0} = \frac{0.428}{1.08} = 0.396$$

$$\therefore \frac{t_1}{t_0} = 0.629$$

and $\therefore t_1 = 1.31$ inches.

From the curves in Fig. 1, we find by interpolation the values

x/l	= 0	1/4	1/2	3/4	9/10	1
t/t_0	= 1	.985	.932	.839	.736	.629

Hence, since $l = 20$ inches and $t_0 = 2.08$ inches, the values

t inches	= 2.08	2.04	1.94	1.74	1.53	1.31
x inches	= 0	5	10	15	18	20

define the meridian curve of the strut.

This strut has 12 per cent. less weight and 7 per cent. less air resistance than the parallel strut it is designed to replace.

The correction for lateral wind load would be negligible.

Example IV.

To design a tapered solid strut, consisting of a parallel middle piece and two conical ends, to replace a parallel solid strut of circular section, 1 inch in diameter and 18 inches long, with the same data as in Example I.a.

Proceeding as in Example III., we find that $t = 1.02$ inches. Subtracting

1%, as in § 6, we find that the diameter of the parallel middle piece is to be 1.01 inches. Its length is to be 7.2 inches, being 40% of the total length. The end diameter t_1 is given by the condition that 10% of weight is to be saved.

$\therefore\ t_1 = 0.80$ inches.

Hence, the strut consists of a parallel middle piece, 1.01 inches in diameter and 7.2 inches long and two conical ends each 5.4 inches long and tapering to an end diameter of 0.80 inches.

APPENDIX II.

CRINKLING STRESS OF STEEL TUBES.

With regard to the *existence* of crinkling stress, we have hitherto made no remarks about tubes that have received any special scientific heat treatment, such as "normalised" tubes; we have confined ourselves to tubes, whether M.S. or H.T.S., that have been, in ordinary commercial language, "thoroughly annealed." We believe ourselves that normalised tubes of fine gauge and large diameter, say, 3in. dia. 22G, would probably be found to show a crinkling stress much below their tensile yield point. In any case we think that if they are welded or brazed, or even silver soldered, they are probably in the process annealed to an unknown extent by the workman who does the job, and may, when used as struts, fail locally at the low stresses to which we have drawn attention; this depends on the workman.

As for the *explanation* of crinkling stress, we believe that it is of the nature of elastic instability. It may be possible, by taking extreme care in laboratory experiments, to coax the tubes to support more than their crinkling stress without failure; possibly the region just above crinkling stress is one of small, but still positive, stability.

There may be an analogy with the stalling angle of aeroplanes. It is said that a clever pilot can often, under good conditions, coax an aeroplane gradually to fly at a higher angle of attack than what is usually found to be the stalling angle. Certainly if careful precautions are taken water can be cooled below 32° F. But we feel that in practical engineering such exceptionally favourable conditions do not generally exist and designers of aeroplane struts should be warned of the danger of such artificial stability.

Our view of the physical nature of crinkling is supported by the fact that a little case-hardening of mild steel tubes is found to raise their crinkling stress considerably, without a corresponding increase in their tensile strength. This can be explained from our point of view by the obvious fact that the tube is stronger in the bending which occurs in crinkling, because the outer fibres have been strengthened.

It might be thought that crinkling matters less in longer struts, in which bending is more important than direct compression. This may not follow, since an inward crinkle reduces the moment of inertia of the section where it occurs and moment of inertia is important in long struts.

CORRESPONDENCE.

THE RELATIVITY OF MASS.

To the Editor of THE AËRONAUTICAL JOURNAL.

SIR,—I have read the article on the above in THE AËRONAUTICAL JOURNAL for September with much interest, but cannot make out what precise system of relativity is used in treating the cases referred to on p. 283. As I explain later on, there are some more or less arbitrary features in such systems. On the ordinary system of supposing the mass not to vary at all, it would be reckoned that, quite regardless of the points of the compass towards which their motions were directed, two equally loaded trucks running at 20 miles an hour would have twice the kinetic energy of one, and take twice as much work to be started from rest and brought up to speed as one. In the article referred to, however, what I should call the difference of the squares of $v+u$ and $v-u$ is taken instead of the sum, about halfway down p. 283, when $v-u$ is in the opposite direction to $v+u$, as if points of the compass were taken account of, contrary to the ordinary rule. Hence I conclude that some special relativity system is used here. Moreover, the velocities relative to the earth of D and G are put down as $v+u$ and $v-u$ respectively, whereas (taking the slope of the inclined planes to be at an angle θ) these would, on the usual system, be $\sqrt{(v^2+u^2+2uv\cos\theta)}$ and $\sqrt{(v^2+u^2-2uv\cos\theta)}$, which somewhat confirms the special system hypothesis, though these, and other discrepancies, could be avoided by altering the conditions slightly. Anyone has a perfect right to assume any self-consistent laws of relative mass he pleases, and to deduce the consequences. There is no difficulty in assuming that a body A has a mass M when it is moving in a given direction at a given velocity V relatively to a body B, and that A's mass will be altered to m, differing from M, if it move at a velocity v, differing from V, along a line (defined by an angle θ), differing from the given line. But it is not possible to discuss the consequences unless a rule be furnished to find m when M, V, v, and θ are known. No rule of this sort being stated in the article, and finding some difficulty in devising one that fits the statements of consequences in the article, I can only hope the author will state the rule himself.

October 29, 1918. MAURICE F. FITZGERALD.

ABSTRACTS.

Modern Aeronautic Engines.

The author has collected together information about a number of high-power engines, such as the Benz, Mercédès, Sturtevant, Thomas, Curtiss, Hispano-Suiza, and the Renault. The information given is: the power, stroke, number of cylinders, compression ratio, weight per B.H.P., and in some cases details of construction, carburettor, exhausts, and cooling system. Photographic illustrations of all the engines are given. (Herbert Chase, "The Journal of the Society of Automotive Engineers," August, 1918.)

Exhaust Headers and Mufflers for Aeroplane Engines.

Some typical exhausts are described and illustrated. In the Curtiss type a manifold is illustrated which terminates in a tapering tube slotted longitudinally on both sides; the reduction of power is said to be very little and the noise is greatly reduced. There are some notes on the design of manifolds, and it is suggested that the results of blower practice should be of assistance. A chart is given showing the loss of velocity due to bends, from which it is seen that the loss diminishes rapidly at first with increase of radius, but remains constant when the radius of the bend is more than $2\frac{1}{2}$ times the diameter of the pipe. Designs of various types of mufflers are shown, and a table is given showing the diameter of the exhaust for powers from 30 to 300 B.H.P.; it is suggested, however, that the best means of determining the exhaust diameter is by trial. Experiments made with the Curtiss muffler, previously referred to, indicated an increase of power in the engine, and it is suggested that this was due to the velocity of the gases, producing a partial vacuum. (Archibald Black, "The Journal of the Society of Automotive Engineers, August, 1918.)

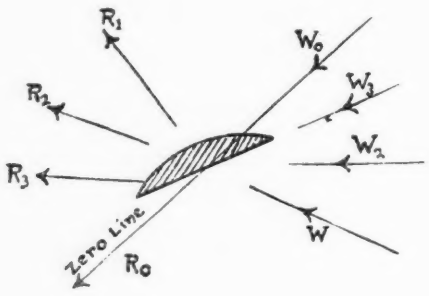
Conventional Propeller Calculations.

The main purpose of this paper is to show how calculations are to be made to predict the strength, horse-power absorbed, and efficiency of a propeller. A graph is given, by means of which the propeller diameter can be ascertained, also the maximum speed and the horse-power, and a second graph enables propeller efficiency to be determined. Some remarks are made in respect of the materials to be used for the propellers and photographs of failures on test are given, including that of an all-steel propeller, welded together by means of oxy-acetylene process. There are some particulars of adjustable propellers and several numerical examples relating to climbing rates and the calculation of efficiency whilst climbing at various altitudes. (F. W. Caldwell, "The Journal of the Society of Automotive Engineers," August, 1918.)

Air Propulsion.

In Professor Morgan's paper it was shown that thrust was due in greater degree to velocity and less to blade disc area than is commonly supposed. There were several speakers, some of whom agreed and others disagreed, but considered that the paper contained ideas of some originality. Mr. G. De Bothezat agreed generally with the author, and argued that for every direction of attack of air

striking the propeller blade there is a corresponding resistance, as shown in the figure. For some particular direction W_0 the resistance R_0 is in the same



direction—*i.e.*, there is no normal component. This he calls the zero line, and it is the "effective pitch" of the propeller. It is always greater than the "geometric pitch," and from measurements he had taken the angle between the two varied from 3° to 12°. He further shows that if slip is calculated on the "effective pitch," it is always positive, whereas if calculated on the "geometric pitch" it may be negative. In his view the use of "effective pitch" explains the difficulties arising out of the experiments of Professor Brooks. He further works out formula for calculating the velocity of the air before and after the propeller. (Professor Morgan Brooks, "The Journal of the American Society of Mechanical Engineers," August, 1918.)

To Ascertain the Speed and Direction of Aeroplanes Over the Water.

The practicability of flying over long stretches of water is handicapped by the difficulty of determining the direction and speed of flight. Admiral Fiske proposed a means of overcoming this difficulty based on the idea of making an aeroplane follow the same general procedure as a ship does.

For long flights over water the machine should be made to fly quite close to the water and steer a straight course, not only laterally, but vertically, thus enabling the pilot to obtain information concerning the direction and speed of flight from the water itself by means of what may be called "an aeroplane log."

The direction can be ascertained by towing through the water a small object by means of a long and light steel wire. The wire will always be in the vertical plane containing the flight path, and the direction may be found by attaching the log line to the end of a pointer moving under the compass or to a "dumb compass" kept in agreement with the compass.

To find the speed it would be necessary merely to tow a "Massey's log"—a simple contrivance towed by a ship and consisting of a sort of box fitted with a propeller that actuates dials on the surface of the box when it turns. The dials indicate the distance the box has been towed, and knowing the time, the speed can be determined. The error that might be made in calculating the speed is estimated at 2 per cent. ("Aerial Age Weekly," July 22, 1918.)

Notes on Glue.

Ideal glue brings in possibilities of high-speed construction, labour economy, and appreciable saving of wood. The current production of ply wood is of high excellence, but the aim should be for still higher quality. The gap to be bridged is illustrated in the elaborate process of sewing mahogany boat and seaplane

hulls with copper wire. Further, in connection with wing spars, the H-type girder involves a waste of 30 per cent of the wood in shavings and chips as at present constructed. The ultimate end of glueing is to produce a correct representation of a continuous piece across the joint. Uniformity cannot be expected unless the glue be prepared in accordance with a rigidly enforced recipe. It must consist of a definite mechanical mixture having a definite chemical composition and susceptible of accurate reproduction.

Perhaps the greatest bar to progress is the difficulty of knowing the result desired. Some tensile strength is needed which should remain when the glue is set, and the glue should have the power of permeating through the surface of a piece of wood. It is also necessary to measure this permeating quality, and to ascertain whether it falls off with dilution or concentration.

Assuming that the ideal glue has been found, it is probable that it should be applied at some standard fluidity and temperature, and that the make-up water should not be tap water, since it is hardly likely that the well-known deposit of chalk can add either to the adhesiveness or tensile strength of the glue.

Further, it must be determined how far dampness or dryness of the wood at the time of glueing affects the glue; the relation, if there be one, between the strengths in compression, tension, and shear of the glue itself should be found, in addition to the ability of the glue to form a good entry into the pores of the wood.

More information is needed on the problem of treating the glue after application for rendering it insoluble in water without detracting from its hold on the wood or its tensile or other properties.

Investigations are in progress to discover how to prevent glue becoming a culture ground for micro-organisms that breed and turn it into water.

Glue is by no means the only possible adhesive; all gums, gelatines, and colloids are open to use; shellac has its possibilities, and is water-resisting.

The fact that linen is fastened to the framework of an aeroplane by means of tacks testifies to the need of scientific inquiry into the matter of adhesives. (Lieutenant-Colonel M. O'Gorman, "Aerial Age Weekly," July 22, 1918.)

Notes on Glue.

The article is a sequel to a discussion opened by Lieutenant-Colonel O'Gorman in "Aerial Age Weekly" of July 22. It deals mainly with the qualities that glue used for constructing aeroplanes (particularly three-ply wood) should possess. It should have adhesiveness to a high degree, and should not deteriorate through bacterial action or vibration when in use. Moreover, for aircraft work it should be water resistant. In order that a ply wood may be classed as water resistant, it should not merely fail to fall apart when saturated with water, but the glue should be of such a quality that it retains a high percentage of its adhesiveness when the ply wood is saturated, and a shearing test should be applied to ascertain if the glue is really entitled to be called waterproof.

In view of the severe conditions which aerial work must meet, it is suggested that glues ought to be classified as non-water resistant, semi-water resistant, and water resistant, with specifications drawn to distinguish the three grades, and thus stimulate investigation which will improve each grade. (Dr. W. R. Drushel, "Aerial Age Weekly," August 26, 1918.)

ABRIDGMENTS OF RECENT PATENT SPECIFICATIONS (AERONAUTICS).

COMPILED BY MR. H. T. P. GEE, PATENT AGENT.

117,776. T. E. C. Wilson, Glenwyllin, Waterloo Park, Liverpool. January 23, 1918. Addition to 107,099.

Aerial Machines without Aerostats; Planes, Construction and Arrangement of.—The aeroplane described in the parent Specification is provided with a pair of triangular planes, extending rearwardly from the lower plane and corresponding to the extensions of the upper plane.

Propelling.—The fuselage is fitted with a tractor and a pusher driven by the same or by separate engines. The side propellers described in the parent Specification are preferably omitted, but may be fitted and driven by a third engine.

Steering.—A rudder is arranged in a gap in the elevator; or a pair of rudders may be provided.

117,926. S. Crowe, 9, High Street, Chislehurst, Kent. July 26, 1917.

Framework for Aircraft, &c.—Spars, girders, struts, etc., for aircraft and other light structures are composed of outer longitudinal members connected together and to one or more intermediate tubular members or cores by series of transverse members. The drawings show upper and lower channels connected to a tube by transverse members, comprising tubes with splayed ends. The members are passed through holes in the tube and secured thereto, or the tube may pass through the members. In another form there are two tubes connected by short lengths of rectangular tubing to members, which are composed of angle-members with their flanges placed together. In still another form the transverse members comprise flanged plates set obliquely. The drawings also show a method of jointing together a spar and web by means of plates. The outer members may be constituted by a tubular structure surrounding the core, and the tubes may be ribbed.

117,930. E. G. Abrahams and J. W. Meek, 5, Albany Courtyard, Piccadilly, London. August 1, 1917.

Aerostats.—Captive and other balloons and dirigible airships are inflated with hot air or exhaust gases from a petrol motor and the temperature maintained by an electric heater. The current for the heater may be supplied through a cable from a source on the ground, or from a generator driven by the engine, or from storage batteries. The envelope may be compartmented or have more than one skin to prevent sudden deflation if ruptured by pressure, or a safety valve may be provided.

Reference has been directed by the Comptroller to Specification 19313/04.

117,947. J. J. Murray, Forty-Second Street, New York, U.S.A. August 8, 1917.

Steering and Balancing; Planes, Arrangement and Construction of.—The main planes of an aeroplane are adapted to have their angle of incidence varied without disturbing the plane bracing and are also adapted to be warped for preserving lateral balance. The drawings show a monoplane in which the two wings are mounted to turn about a front spar mounted at the upper ends of stanchions on the body. A rear spar which forms part of the frame of both wings is rotatably mounted in the upper ends of the vertical limbs of a U-shaped member working in guides in the body. The spar is braced at its lower side by cables to a lever pivoted to the member. A mast comprising downwardly divergent members is mounted on the spars so as to tilt with the plane. Members mounted on ball bearings on one of the spars have ears braced by cables to the mast and

to members of the chassis, stay wires connected to the body preventing outward buckling of the members. One of the members, together with the lever, is raised and lowered to vary the angle of incidence of the planes by pinions or sectors acting on racks on the vertical limbs and operated by levers provided with latches engaging toothed quadrants, or by wheels, on each side of the pilot's seat. The drawings also show a control device comprising a tubular column adapted to swivel about a stud on a fitting which is mounted on a transverse rock shaft supported by brackets from the vertical limbs of the member. A wheel and spindle operate a drum for actuating the rudder. Arms on the shaft are connected by cables to the elevator which is operated by longitudinal swinging movements of the column. Arms are connected by cables to the lever so that lateral movements of the column about the stud warp the wings in opposite directions. The invention may also be applied to biplanes and multiplanes.

117,973. V. P. Galle, Phillipsburg, New Jersey, U.S.A. August 21, 1917.

Balancing; Cars.—The control cables from the ailerons of an aeroplane are connected to the ends of a sliding plunger which is carried by the medial struts and is moved automatically to preserve the lateral balance of the machine by tilting movements of the seat. The amplitude of motion may be adjusted by collars movable over graduated parts of the plunger. The plunger is guided through the struts by rollers pressed against the plunger by springs in the struts, and is normally retained in its mid-position by springs in casings. Motion is transmitted from the seat to the plunger by rods having slots engaging pins. The seat is pivoted above its centre of gravity to a plunger guided within a casing secured to the lower plane and supported by a spring.

117,998. R. E. Roberts, 2, Florence Terrace, Northland Road, Londonderry. September 18, 1917.

Propelling.—Aeroplanes having double or multiple engines geared to propellers have means controlled by a single lever for obtaining various engine and propeller combinations. The drawings show a device applicable to two engines and two propellers. The propellers are driven from shafts geared to clutches adapted to engage the fly-wheels of the engines. The clutches are controlled by two levers having adjustable fingers engaging the underside of a cam. The cam is connected to a lever having a projection which engages grooves cut in the upper or under surface of a fixed plate resembling the gate quadrant of a motor-car. When the lever is in a central position both clutches are in engagement, but in the forward and rear positions one or other of the clutches is engaged and the other disengaged. In addition, the shafts are adapted to be coupled and uncoupled by clutch members, one of these members being controlled by a lever connected to the lower end of the lever which can swing laterally about a pivot. When the lever is in a position to pass through either gate in the quadrant for the purpose of actuating the member the cam disengages both of the clutches.

118,028. Blackburn Aeroplane & Motor Co., Olympia, and J. W. Copley, Wynberg, Fernville Avenue, Roundhay, both in Leeds. November 13, 1917.

Locking Tension Members of Aircraft, &c.—In means for locking tension members of aircraft and other structures, particularly where the tension members are screw-threaded into connecting devices, a piece of wire is bent round the tension member and secured thereto, as by soldering, and then bent round the connecting device or passed through a pin or other part thereof.

118,029. Blackburn Aeroplane & Motor Co., Olympia, and J. W. Copley, Wynberg, Fernville Avenue, Roundhay, both in Leeds. November 13, 1917.

Locking Tension Members of Aircraft, &c.—In means for locking tension

members of aircraft and other structures as described in Specification 118,028, in which a piece of wire is secured to and bent round the tension member and then secured to the connecting device, the wire is secured to a collar on the tension member by being passed through a hole in the collar or bent round a projection thereon. The drawings show the invention applied to a turn-buckle coupling.

118,049. J. Dehouck, 18, Rue des Dixmude, Ypres, Belgium. January 8, 1918.

Aerial Machines without Aerostats; Planes, Arrangement of; Cars; Steering and Balancing.—The main planes of an aeroplane are carried by a ring arranged to rotate on an inner ring to which is secured the fuselage and in which is loosely mounted a transverse axle rigidly secured to the inner undercarriage and car. The planes are thus set free to rotate about the ring and to tilt about the axle for automatic balancing; or such adjustment of the planes may be obtained by manual operation of the elevator and rudder.

Propelling.—The propeller shaft is mounted in bearings rigidly connected to the axle at right angles to a line passing through the axle and the centre of gravity of the whole apparatus.

118,099. A. Cardoso, 4, Piazzale Monforte, Milan, Italy. July 17, 1918. Convention date, July 5, 1917. Not yet accepted. Abridged as open to inspection under Section 91 of the Act.

Propelling Aircraft, Ships, and Vehicles.—Apparatus intended for propelling air, land, or water vehicles comprises a casing closed at its front end, which is mounted in or secured to the vehicle and provided at its open rear end with a screw or other rotary or reciprocatory propeller arranged to produce a vacuum in the casing. A valve is arranged in front of the propeller.

118,123. H. S. Harris, Buckland House, Esher, Surrey. August 16, 1917.

Turbines.—A motor producing a gaseous stream for propelling aircraft, vessels, or vehicles by direct reaction, or for driving a turbine, comprises a combustion chamber from which the combustion products issue in the form of a non-expanding stream into an open-ended discharging tube, so that air is drawn in as the stream cools to augment the mass of the stream. Petrol, paraffin, or coal dust may be used as fuel. The drawings show two petrol jets supplied from a tank and arranged in tubular portions of a fan casing. The fan is driven by a small petrol motor and delivers air at low pressure to combustion chambers which are enlarged to permit expansion of the combustion products, the ends of the chambers being contracted to increase the velocity of the jets. Rearwardly tapering tubes open at both ends surround the chambers. Additional air may be introduced at several points along the tubes. A series of nozzles or burners may be used in any convenient arrangement, or one or more nozzles may discharge into a single tube of large cross-section which may accommodate the pilot, tank, and engine at its forward end. Instead of supplying air for combustion from a fan, it may be supplied through a collector during forward motion. The air current may induce petrol into the burner, or *vice-versa*. For starting the engine a fan may be provided in the tube for drawing in air and petrol, and the discharging end partially closed by a valve. A fan driven by the stream in the tube may also drive the fan. The tube or tubes may be angularly movable for steering purposes. The tube or tubes may be reversed for retarding the speed of the aircraft when landing, or the rear end may be temporarily closed so that gas is discharged from the front end.

118,240. A. V. Roe, High Firs, Bursledon, near Southampton. March 20, 1918. Addition to 17740/15.

Wire-Strainers.—In the device described in the parent Specification, the cupped portion of the forked body member and the shoulder of the nut are made partly spherical in shape so as to act as a ball-and-socket joint and allow lateral movement of the stay wire without risk of injury. Locking is effected by a wire as previously described and by a lock-nut carried by the screwed end of the stay wire. Where the stay wire is secured to a spar of the aeroplane a spring locking washer is employed having lugs adapted to engage squared faces on the shouldered nut and spring arms provided with lugs to embrace the arms of the forked body member. A lock-nut serves to secure the washer to the screwed end of the stay rod which may be provided with flats to lock the washer positively in position.

118,341. J. Ashworth, 348, Brunswick Avenue, Toronto, Canada. September 4, 1917.

Aerial Machines without Aerostats; Propelling; Steering and Balancing.—An aerial machine is supported by pairs of planes yieldingly pivoted on shafts carried by rotating arms, means being provided for varying the initial incidence of the planes in the same or opposite directions on the two sides of the machine. Auxiliary balancing planes are operated simultaneously with the adjustment of the rotating planes, the adjustment being in the same direction as the main planes when the main planes are all moved in the same direction, but when the main planes are moved in opposite directions certain of the auxiliary balancing planes are each moved in a contrary direction to the adjacent main planes. The arms are journaled upon two sleeves and are driven from a motor by chains passing over sprocket wheels on certain of the arms. The supporting planes are connected at each end by springs to pins on sprocket wheels geared to similar sprocket wheels on the sleeves. The sleeves are mounted on a continuous shaft, and have bevel wheels gearing with a wheel fixed to a vertical shaft. A second wheel gears with two wheels mounted on shafts carrying the auxiliary balancing planes. An horizontal shaft provided with a hand-wheel is connected to the shaft vertical by gearing contained in a casing. Longitudinal movement of the shaft horizontal turns the sleeves and varies the normal angle of the planes so as to alter the line of thrust equally on the two sides of the machine, the auxiliary balancing planes being also turned in the same direction as the main planes. The centre of gravity also is moved. Rotation of the horizontal shaft causes the rotating planes to be turned in opposite directions to effect steering, the auxiliary balancing planes being turned in opposite directions to the corresponding rotating planes to preserve lateral balance. The gearing also enables the pressures on the two sides of the machine to be automatically equalised during gusts. The car is suspended from the sleeves. The drawings show the positions which the main planes assume at different points in their cycle. When the engine stops, all the planes assume the horizontal position, and their angle of incidence can be controlled during the ensuing glide.

118,352. G. Brewer, 33, Chancery Lane, London, and M. H. Spencer, Roehampton, Surrey. September 24, 1917.

Pitot-Tube Apparatus.—In order to support a Pitot tube outside the influence of the current of air diverted by the windscreen or car of a kite balloon, the tube is bent as shown and carried by a bar having a downwardly extending member provided with yokes to embrace the vertical car line connected to its supporting bar, the bar being secured by rubber loop connections. Struts flexibly connected to the first-mentioned bar are connected to the diagonal car lines by yokes and loop connections.

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